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[54] **CONTROL SYSTEM OF AN EXCAVATOR**

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[51] **Int. Cl.**[6] **E02F 3/32**

[52] **U.S. Cl.** **172/4.5**; 37/348; 414/699; 364/424.07

[58] **Field of Search** 37/347, 348, 382, 37/383; 172/2, 3, 4, 4.5, 7, 9, 10, 11; 364/424.06, 424.07, 424.1; 414/694, 699, 379

[56] **References Cited**

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4,888,890	12/1989	Studebaker et al.	37/348
5,160,239	11/1992	Allen et al.	172/4.5 X
5,356,259	10/1994	Hanamoto et al.	37/348 X

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Assistant Examiner—Robert Pezzuto
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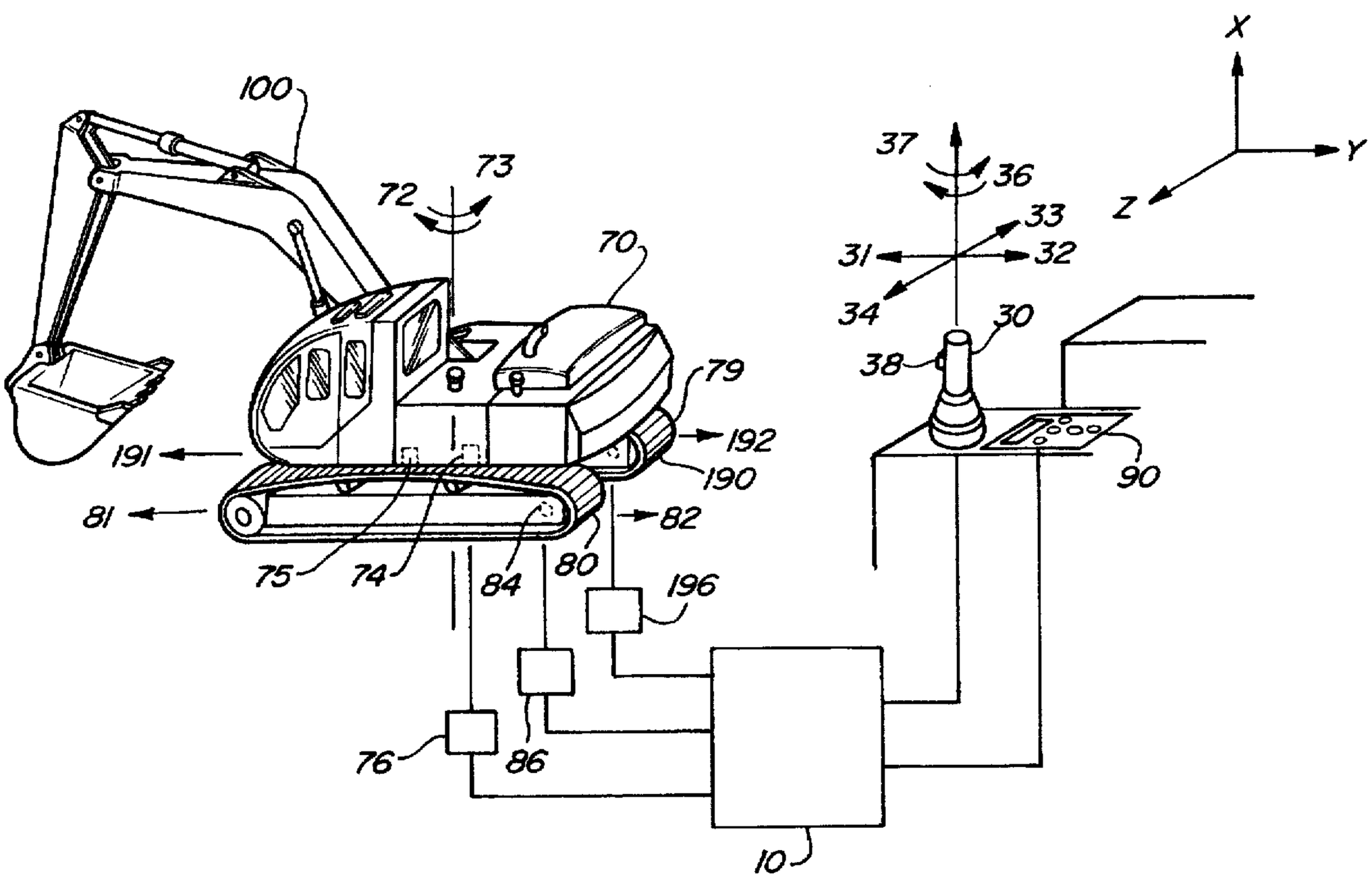
[57] **ABSTRACT**

A control system of an excavator. The excavator includes a lower running body, an upper pivoting body, a working device having a plurality of links attached to the upper pivoting body, a pivoting device, and a running device, actuators for actuating the working device, the pivoting device, and the running device, hydraulic control valves for controlling quantities of hydraulic fluid supplied to the actuators, sensors for detecting relative angular positions of the links, and a control system. The control system includes a pair of manipulating devices each of which can be manipulated in at least three directions so as to output electrical signals proportional to deviated amounts in selected directions among the directions from a neutral position thereof, a switch board on which a plurality of function switch are installed, for outputting a signal in accordance with a selected function and displaying the selected function, a control section for controlling quantifies of hydraulic fluid supplied to the hydraulic cylinders and the hydraulic motors by receiving signals from the manipulating device, the switch board, and the angle detecting sensors and transferring the signals to the hydraulic control valves.

16 Claims, 3 Drawing Sheets



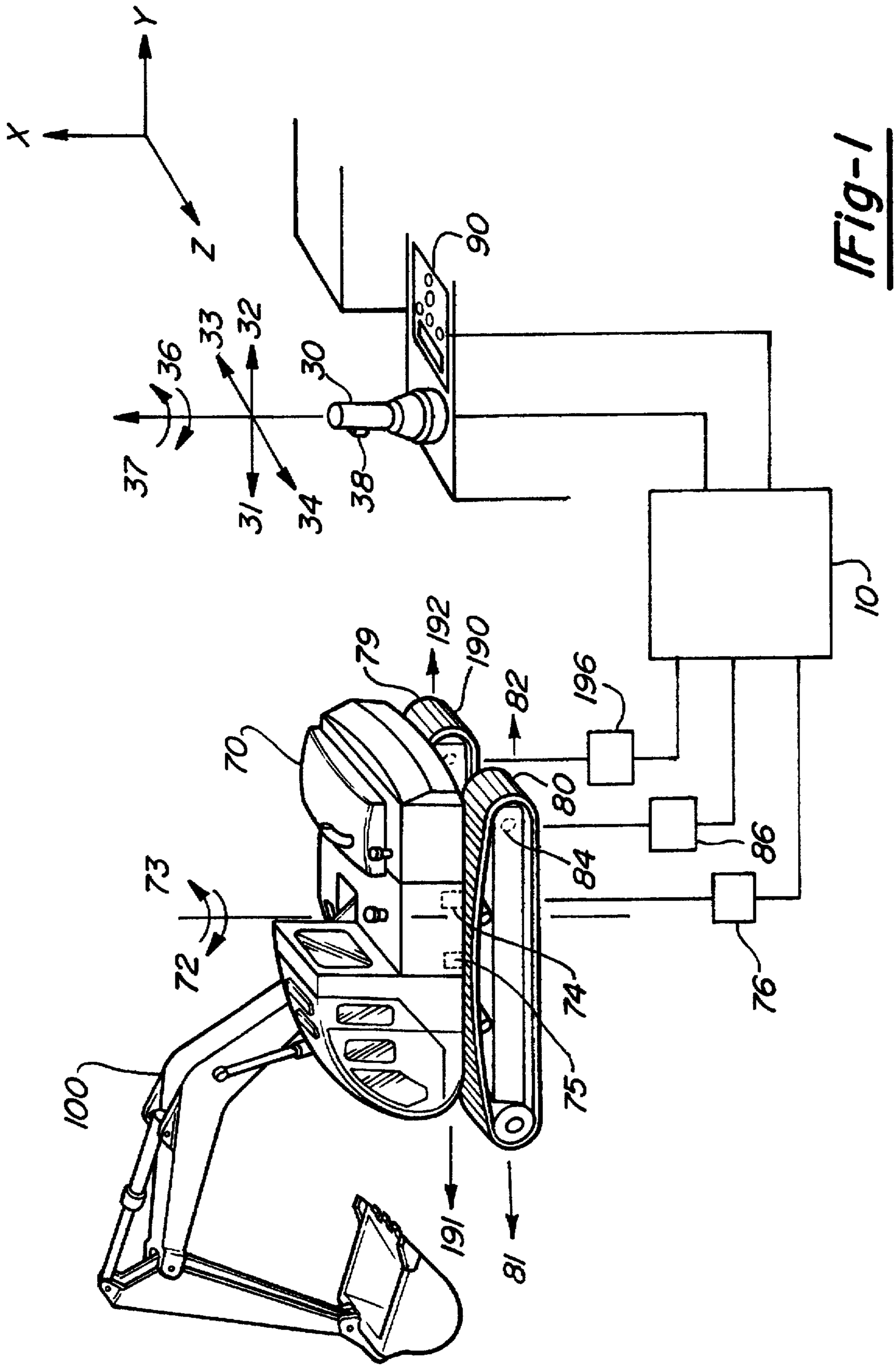

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Fig-1

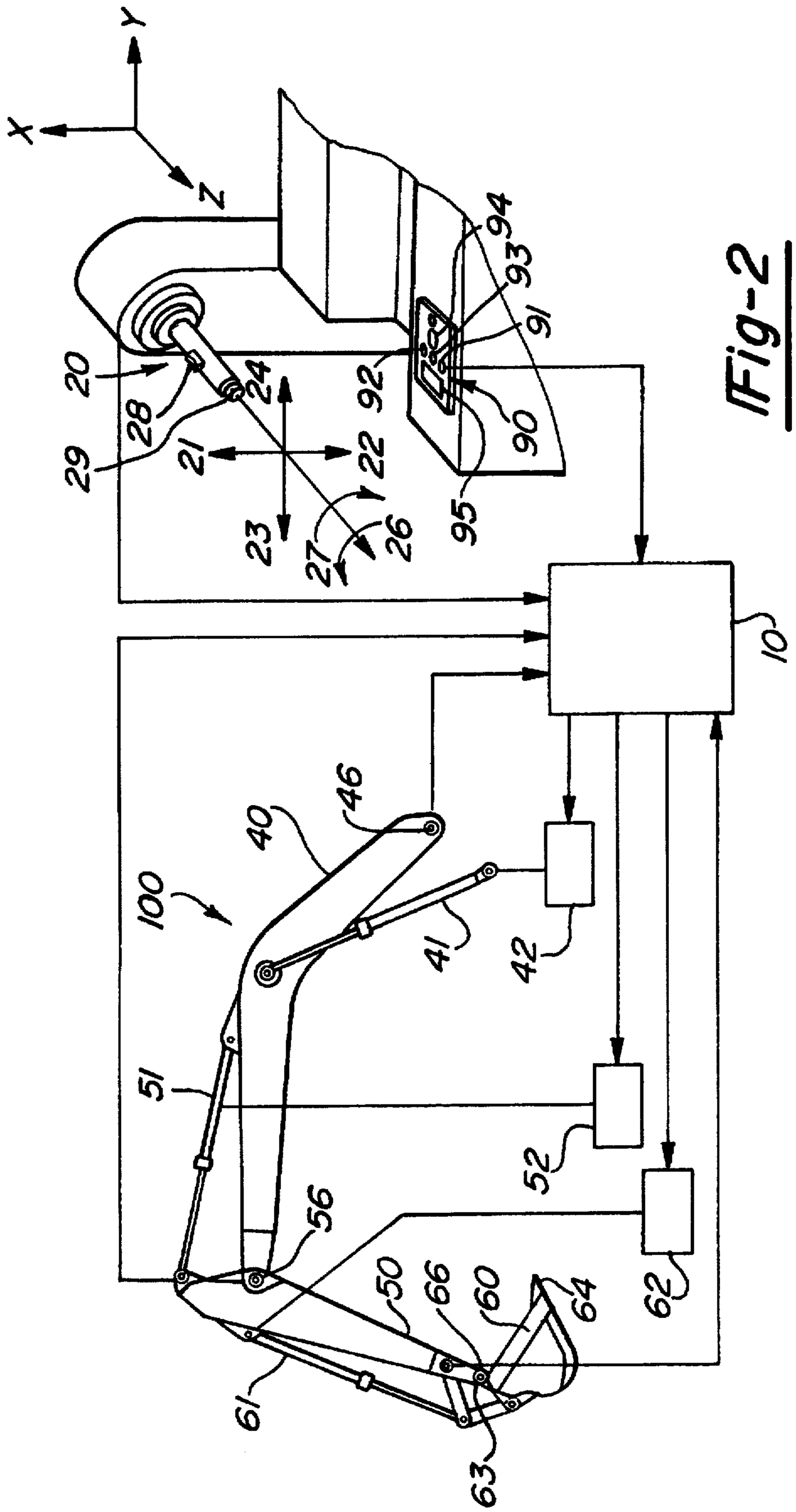
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Fig-2

Fig-3

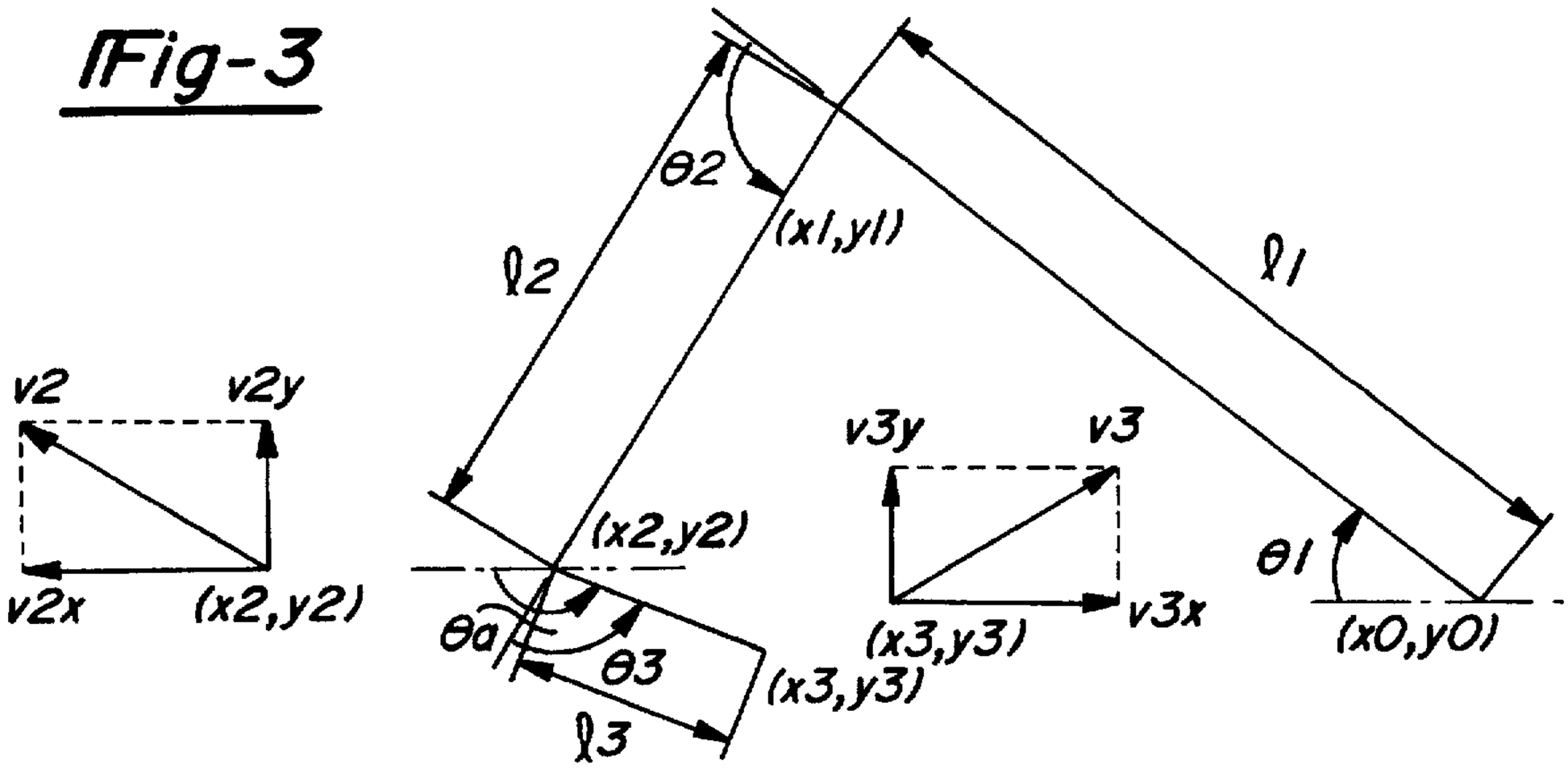
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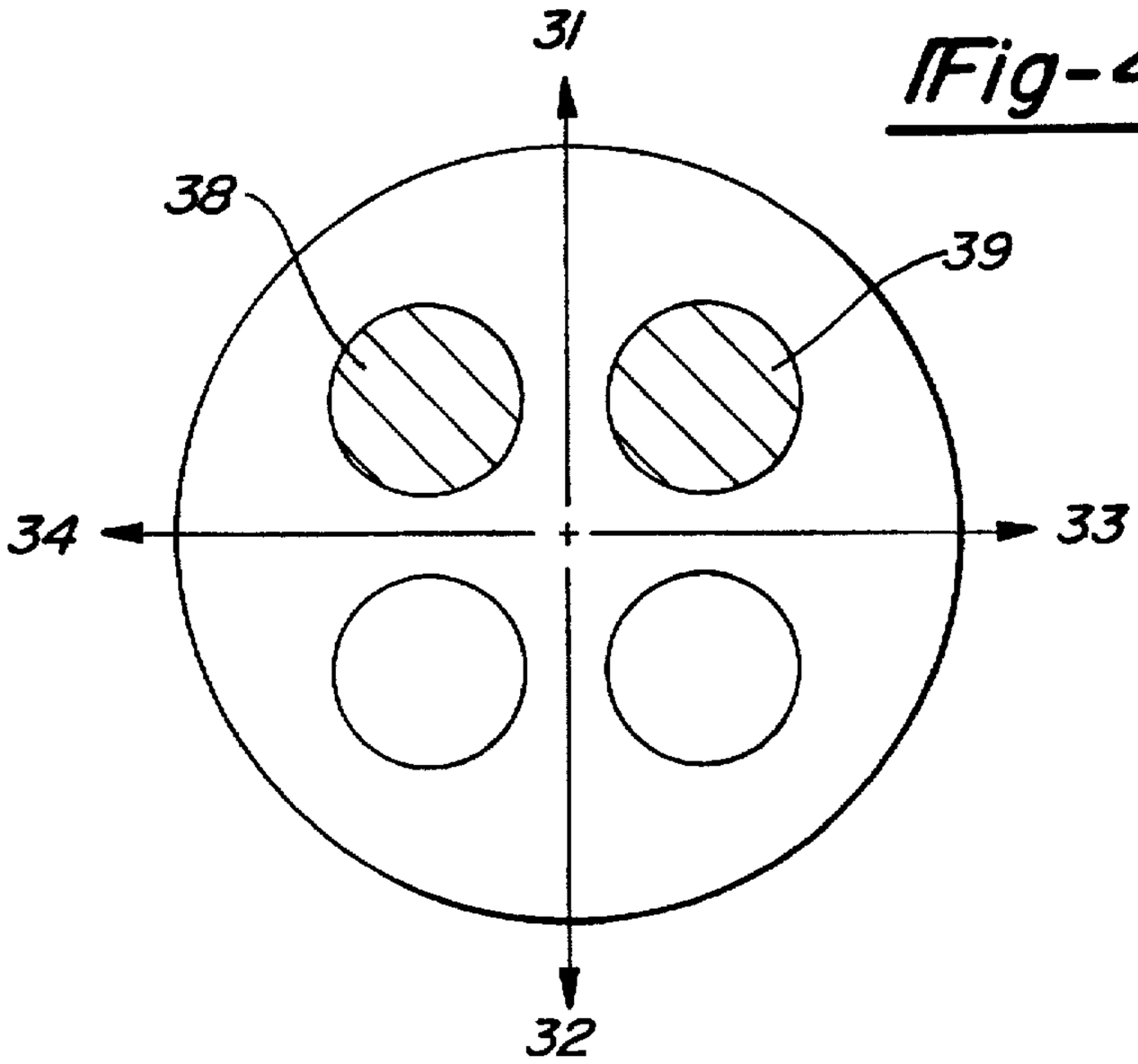
Fig-4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CONTROL SYSTEM OF AN EXCAVATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a control system of an excavator, and more particularly to a control system of an excavator which can easily manipulate a working device of the excavator by providing direct controlling relations between the working device and manipulating devices so that operations of the working device can be logically interconnected with the operations of the manipulating devices.

2. Description of the Prior Art

Conventionally, an excavator includes a working device which comprises a plurality of links, a pivoting device, and uses manipulating devices having several levers or pedals in order to manipulate the excavator.

However, in a conventional excavator, since the logical relations between the manipulating devices and working devices are not clear, an unskilled worker cannot easily accomplish works such as levelling works which need high-level operational skills. Further, much time and effort is needed to be accustomed to the high-level operational skills. In addition, work efficiency is lowered due to worker's fatigues and stresses during the manipulation of the excavator, even for a skilled worker.

In order to overcome the above-mentioned disadvantages, devices for determining the position of links and pivot points using miniature models are disclosed in U.S. Pat. No. 4,059,196, Japanese Patent Laid Open No. 87-33944, Japanese Patent Laid Open No. 93-257551. However, in excavators using the devices, it is necessary to determine the position continuously during work, in order to operate excavators, and the structures of the devices are complex.

Further, excavators which enable intuitional manipulations by installing manipulating devices in horizontal planes which directions are the same as those of planes on which the excavators are laid, in stead of installing the devices in vertical planes, are disclosed in Japanese Patent Publication No. 83-22613, Japanese Patent Laid Open No. 84-131066, U.S. Pat. No. 5,160,239, U.S. Pat. No. 5,424,623, EP03616666A1, Japanese Utility Model Laid Open No. 92-134570, and Japanese Patent Laid Open No. 91-275819. Nevertheless, the excavators have disadvantages in that they has no sufficient solutions to prevent safety accidents during work, and pivoting and running manipulations are still difficult.

On the other hand, excavators in which manipulating modes of excavators are different from one another, and in which a user can select a wanted manipulating mode is disclosed in Japanese Patent Laid Open No. 93-156665, Japanese Patent Laid Open No. 89-31153, and Japanese Patent Laid Open No. 92-30034. But, in the excavators, only few correlations between working devices and working devices are considered, so a great effort is needed to be skilled in the manipulating modes by a user.

SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a control system of an excavator in which a working device of several links, a running device, and a pivoting device can be easily manipulated with hands.

It is another object of the present invention to provide a control system of an excavator which can easily manipulate a working device with multi-degree of freedom by providing

direct controlling relations between the working device and manipulating devices so that operations the working device can be logically interconnected with the operations of the manipulating devices.

It is another object of the present invention to provide a control system of an excavator in which a user can be easily accustomed to the manipulating techniques by easily selecting needed functions of the excavator.

In order to achieve the above-mentioned objects of the present invention, there is provided an excavator comprising: a working device having a plurality of links comprising a boom attached to a tip of an upper pivoting body pivoting with respect to a lower running body, an arm attached to a tip of the boom, and a bucket attached to a tip of an arm; a pivoting device for driving and pivoting the upper pivoting body with respect to the lower running body; a running device for driving left and right chain belts of the lower running body; hydraulic cylinders and hydraulic motors for actuating the working device, the pivoting device, and the running device; hydraulic control valves for controlling quantities of hydraulic fluid supplied to the hydraulic cylinders and the hydraulic motors; a boom angle detecting sensor installed between the upper pivoting body and the boom, for detecting a relative angular position of the boom with respect to the upper pivoting body; an arm angle detecting sensor installed between the boom and the arm, for detecting the relative angular position with respect to the boom, a bucket angle detecting sensor installed between the boom and the bucket, for detecting the relative angular position with respect to the arm; a control system having a pair of manipulating devices each of which can be manipulated in at least three directions so as to output electrical signals proportional to deviated amounts in selected directions among the directions from a neutral position thereof, a switch board on which a plurality of function switch are installed, for transferring a signal in accordance with a selected function and displaying the selected function, a control section for controlling quantities of hydraulic fluid supplied to the hydraulic cylinders and the hydraulic motors by receiving signals from the manipulating device, the switch board, and the angle detecting sensors and transferring the signals to the hydraulic control valves.

According to the first aspect of the present invention, the pair of manipulating devices are a first manipulating device installed on a vertical manipulating plane, for driving the working device in accordance with a manipulating direction and an amount thereof and a second manipulating device installed on a horizontal manipulating plane, for driving the running device and the pivoting device in accordance with a manipulating direction and an amount thereof, the vertical manipulating plane having a same direction as a direction of a working plane of the working device.

According to the second aspect of the present invention, the first manipulating device is manipulated in a first manipulating direction which is a first coordinate axis, in a second manipulating direction which is a second coordinate axis, and in a third manipulating direction which is a rotating direction about a third coordinate direction perpendicular to a plane formed by the first and second coordinate axes.

According to the third aspect of the present invention, the second manipulating device is manipulated in a first manipulating direction which is a first coordinate axis, in a second manipulating direction which is a second coordinate axis, and in a third manipulating direction which is a rotating direction about a third coordinate direction perpendicular to a plane formed by the first and second coordinate axes, the

manipulating directions being respectively corresponding to a forward or rearward running operation of the running device, a left or right turning operation of the running device, and a left or right pivoting operation of the pivoting device.

According to the fourth aspect of the present invention, a pivot safety switch is installed on an outer surface of the second manipulating device so as to send a signal about the third manipulation direction of the second manipulating device when the switch is on.

According to the fifth aspect of the present invention further comprises a pivot detecting sensor installed between the upper pivoting body and the lower running body, for detecting the relative angle of the upper pivoting body with respect to the lower body and transferring an angle signal to the control section.

According to the sixth aspect of the present invention, forward and rear movement of the lower running body is controlled so as to coincide with the first manipulating direction of the second manipulating device in accordance with whether the relative angle of the upper pivoting body with respect to the lower running body detected by the pivot detecting sensor is above 180 degree or not.

According to the seventh aspect of the present invention, a levelling switch for determining whether working ground surface should be levelled or not, a bucket angle switch for determining whether the absolute bucket angle should be maintained uniformly or not during the work, an ground angle switch for determining the inclined angle of the working surface during the levelling work, a mode conversion switch for converting the operational mode to a manual mode or an automatic mode are installed on the switch board, the switch board being provided with a display section for displaying information about operational states and modes of the excavator.

According to the eighth aspect of the present invention, in case of the manual mode, operations of the boom, the arm, and the bucket are respectively controlled by the first, second, and third manipulating directions.

According to the ninth aspect of the present invention, in case of the automatic mode, a pivot point of the bucket is determined by the first and second manipulating directions and manipulated amounts in the directions, and the bucket is manipulated by the third manipulating direction and manipulated amount.

According to the tenth aspect of the present invention, further comprises a bucket selection switch installed on an outer surface of the first manipulating device, for transferring a signal to the control section about manipulated directions along the direction, and the manipulated amounts of the first manipulating device while the switch is on.

According to the eleventh aspect of the present invention, when the bucket angle switch is selected during the automatic mode operation, the absolute bucket angle is uniformly maintained by manipulating the relative bucket angle with respect to the arm, and during the operation of the bucket, the bucket is manipulated regardless of the other manipulations so that the absolute bucket angle is reset to a new value.

According to the twelfth aspect of the present invention, if the levelling switch is selected, the automatic mode is automatically selected, and a position of a bucket tip is determined by the first and second direction manipulation and manipulated amounts of the first manipulating device in the automatic mode, in accordance with the detected relative boom angle with respect to the upper pivoting body, the detected relative arm angle with respect to the arm, and the detected relative bucket angle with respect to the arm, the bucket being manipulated by the third manipulating direction and amount in the direction.

According to the thirteenth aspect of the present invention, if both the levelling switch and the bucket angle switch are selected, the position of the bucket is determined and controlled by the manipulated direction and amount in the automatic mode of the first manipulating device, and then if a signal in accordance with the third manipulating direction is transferred to the manipulating device, the bucket is manipulated regardless of the other manipulations, and then if a bucket operational signal is not transferred to the manipulating device, the absolute bucket angle is maintained uniformly.

According to the fourteenth aspect of the present invention, the excavator further comprises a switch installed on a tip of the first manipulating device and connected to the control device, for controlling a point determined by the first manipulating direction and amount while the switch is on, so that the point is moved on a plane selected by the switch.

According to the fifteenth aspect of the present invention, if the switch is on during the levelling work, the bucket tip determined by directions and amounts of the first and second manipulating direction is moved in a working plane having a certain angle selected by the ground angle switch.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and other advantages of the present invention will become more apparent by describing in detail a preferred embodiment thereof with reference to the attached drawings, in which:

FIG. **1** is a perspective view for showing an excavator according to an embodiment of the present invention, and particularly for showing a control system of a pivoting device and a running device of the excavator.

FIG. **2** is a perspective view for showing a control system of a working device of the excavator of FIG. **1**.

FIG. **3** is a perspective view for showing positions of pivot points of the working device of FIG. **2**.

FIG. **4** is a perspective view for showing arrangements of inner sensors of a manipulating device of the control system of FIG. **1**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereinafter, a preferred embodiment of the present invention will be described in detail with reference to the accompanying drawings.

FIG. **1** schematically shows a control system of a pivoting device and a running device of an excavator according to an embodiment of the present invention, and FIGS. **2** and **3** schematically shows a control system of a working device of the excavator of FIG. **1**.

As shown in FIGS. **1** and **2**, the excavator is provided with a working device **100**. The working device **100** comprises a boom **40**, an arm **40**, and a bucket **60**. The boom **40** is connected to the pivoting body **70** of the excavator at one end thereof, and to one end of the arm **50** at the other end thereof. The bucket **60** is a working tool of the excavator and is connected to an end of the arm **50**.

The excavator comprises a lower running body **79**, an upper pivoting body **70**, and a working device **100**. The upper pivoting body **70** is pivotally mounted on the lower

running body **79**. The working device **100** is mounted on the upper pivoting body **70** at the front portion of the upper pivoting body **70**, and has a plurality of joints so that the angular positions of the links such as the boom **40** and the arm **50** can be varied.

The working device **100** moves in a two dimensional plane as either the boom **40** or the upper pivoting body **70** is pivoted.

The boom **40** is operated by a hydraulic cylinder **41** and moves the working device **100** upward and downward. The arm **50** is also operated by a hydraulic cylinder **51** and moves the bucket **60** towards and away from the pivoting body **70**. The angular position of the bucket **60** is varied when it is operated by a hydraulic cylinder **61** so as to accomplish its excavating operation.

A boom angle detecting sensor **46** for detecting the relative angular position of the boom **40** with respect to the upper pivoting body **70**, an arm angle detecting sensor **56** for detecting the relative angular position of the arm **50** with respect to the boom **40**, and a bucket angle detecting sensor **66** for detecting the relative angular position of the bucket **60** with respect to the arm **50** are respectively installed between the boom **40** and the upper pivoting body **70**, between the boom **40** and the arm **50**, and between the arm **50** and the bucket **60**.

The quantities of hydraulic fluid supplied to the hydraulic cylinders **41**, **51**, and **61** are controlled by hydraulic control valves **42**, **52**, and **62** respectively. Further, the quantities of hydraulic fluid supplied to the hydraulic motors **74**, **84**, and **194** are controlled respectively by hydraulic control valves **76**, **86**, and **196** during the pivoting and running operations of the excavator. The hydraulic control valves **42**, **52**, **62**, **76**, **86**, and **196** are connected to the control section **10** which is connected to a switch board **90** and first and second manipulating devices **20** and **30**.

A pivoting motor **74** drives the upper pivoting body **70** of the excavator, and left and right running motors **194** and **84** turn the excavator left and right respectively.

The first and second manipulating devices **20** and **30** are respectively installed at positions to the left and right of a user, and vice versa, in front of the user, and move in three dimensional ways.

The first manipulating device **20**, as shown in FIG. **2**, has three manipulating directions, i.e., a first manipulating direction **21** and **22** which is the X coordinate direction, a second manipulating direction **23** and **24** which is the Y coordinate direction, and a third manipulating direction **26** and **27** which is the rotating direction about the Z coordinate direction perpendicular to the plane formed by the X and Y coordinate axes.

On the other hand, as shown in FIG. **2**, the second manipulating device **30**, has three manipulating directions, i.e., a first manipulating direction **31** and **32** which is the Y coordinate direction, a second manipulating direction **33** and **34** which is the Z coordinate direction, and a third manipulating direction **36** and **37** which is the rotating direction about the X coordinate direction perpendicular to the plane formed by the Y and Z coordinate axes.

The first and second manipulating devices **20** and **30** generate signals which are proportional to the amounts of deviation from their neutral positions when they are manipulated. The signals are transferred to the control section **10** when the switch board **90** is manipulated.

The switch board **90** is provided with a plurality of function switches which enable the selection of operational functions already programmed, and hence a user can select wanted functions to be transferred to the control section **10** in order to accomplish the functions.

Installed on the switch board **90** are a display section **95** for displaying various information about the operation of the excavator such as operational states and operational modes, a mode conversion switch **91** for converting the operational mode to manual or automatic modes, a levelling switch **92** which is used in case of the levelling of the inclined ground surfaces, a bucket angle switch **94** for detecting the absolute angle of the bucket **60** during the work, and a ground angle switch **93** for detecting the inclined angle of the ground during the levelling of the ground surfaces.

A potentiometer, an up-down switch, or the like can used as the ground angle switch **93** to enable the continuous detection of the ground angle.

Each of the first and second manipulating devices **20** and **30** is provided with a bucket selection switch **28** and a pivot selection switch **38** on the outer surfaces of their levers, so that the manipulating devices **20** and **30** can be manipulated in their manipulating directions **20** and **30** only when the switches **28** and **38** are on.

The control section **10** receives signals from the switch board **90**, manipulating devices **20** and **30**, and angle detecting sensors **46**, **56**, and **66**, and transfers control signals to the hydraulic control valves **42**, **52**, **62**, **76**, **86**, and **196**. The hydraulic control valves **42**, **52**, **62**, **76**, **86**, and **196** controls the movements of the working device **100**, pivoting body **70**, and running body **79** by controlling the quantities of hydraulic fluids supplied to the hydraulic cylinders **41**, **51**, and **61** and the hydraulic motors **174**, **84**, and **194**.

Hereinafter, the operation of the control system relevant to the working device **100** will explained with reference to FIG. **2**.

The relations between the first manipulating device **20** and the working device, when the mode conversion switch is converted to the manual mode, are as follows.

	first manipulating direction		second manipulating direction		third manipulating direction	
direction of the manipulating device	upward	downward	forward	rearward	counter clockwise	clock wise
operation of the working device	boom up	boom down	arm stretching	arm contracting	bucket closed	bucket open

In case of the manual mode, since the direction of the manipulating plane of the first manipulating device **20** is the same as the direction of the operational plane of the working device **100**, the logical operational relations between the first manipulating device **20** and the working device **100** can be easily recognized by a user, thereby enabling intuitional control of the excavator.

On the other hand, if the automatic mode is selected, the relative angular positions of the boom **40** and the arm **50** are controlled by the control section **10** so that the position of a pivot point **63** can be determined by a combined direction with the first and second manipulating directions **21**, **22**, **23**, and **24** of the first manipulating device **20** and by the manipulating amount along the directions. Then, the manipulating direction and the manipulating amount are inputted to the control section **10**, and the relative angles of the boom **40** and the arm **50** are determined by the control

section **10** and are outputted therefrom. Preferably, the relative angular positions of the boom **40** and the arm **50** are detected by the angle detecting sensors **46**, **56**, and **66**, and then are inputted to the control section **10**. A resolver, a potentiometer, and an encoder or the like can be used as the angle detecting sensors **46**, **56**, and **66**.

The bucket **60** is manipulated by the third direction of the first manipulating device **20**. The signals from the bucket **60** are processed in the control section **10** only when the bucket safety switch is on to prevent unintended operations while manipulating the first manipulating device **20**, so that the bucket **60** is manipulated only by the third direction of the first manipulating device **20**. Therefore, the bucket safety switch **28** should be pressed if a user want to manipulate the bucket **60**.

The control section **10** controls the relative bucket angle and the relative arm angle Θ_1 and Θ_2 to manipulate the pivot point **63** corresponding to the manipulating direction and the manipulating amount of the first manipulating device **20**. The relative angles of the boom **40** and the arm **50** are as follows.

$$\dot{\Theta}_1 = \frac{\cos(\Theta_1+\Theta_2)}{l_1\sin\Theta_2} V_{2x} + \frac{\sin(\Theta_1+\Theta_2)}{l_1\sin\Theta_2} V_{2y} \quad (1)$$

$$\dot{\Theta}_2 = \left(\frac{-\cos\Theta_1}{l_2\sin\Theta_2} - \frac{\cos(\Theta_1+\Theta_2)}{l_1\sin\Theta_2} \right) V_{2x} + \left(\frac{-\sin\Theta_1}{l_2\sin\Theta_2} - \frac{\sin(\Theta_1+\Theta_2)}{l_1\sin\Theta_2} \right) V_{2y} \quad (2)$$

where (x_1,y_1) represents the relative position the bucket **60** with respect to the pivot point **63**, l_1 and l_2 respectively represent the lengths of the boom **40** and the arm **50**, V_2 represents the velocity of the pivot point **63** to be determined, which has a horizontal element V_{2x}, and a vertical element V_{2y}.

If the levelling switch **92** of the switch board **90** is on, the mode is automatically set to be the automatic mode regardless of the selection of the automatic mode. In other words, the relative angle of the bucket **60** with respect to the arm **50** is controlled so that the angle of the bucket **60** can not be limited to a certain angle and can be freely determined, and is controlled so that the relative angle is maintained uniformly during the manipulation. Then, if the bucket **60** is operated by the operational signal of the third manipulating direction, the last bucket angle is reset to an absolute angle of the bucket **60** to be determined.

Preferably, a switch **29** is installed at one end of the first manipulating device **20** so that, when the levelling switch **92** of the switch board **90** is selected, the position of the bucket tip **64** is controlled in a plane having a predetermined angle set by the ground angle switch **93** of the switch board **90**. Then, direction and moving velocity are determined by the manipulation along the second direction. And, then the bucket **60** is manipulated by the manipulating direction and amount if a bucket operational signal by the third manipulating direction **26** and **27** of the first manipulating device **20** is provided by a user.

Further, if the bucket angle switch **94** is selected, the bucket **60** is controlled to maintain an absolute angle.

The position (x_2,y_2) of the pivot point **63** of the bucket **60** for controlling the bucket tip **64** is as follows.

$$x_2=x_3-l_3\cos\Theta_a$$

$$y_2=y_3 l_3\sin\Theta_a$$

where l_3 represents the length of the bucket **60** and Θ_a represents the relative bucket angle with respect to the absolute horizontal plane.

The relative angles Θ_1 and Θ_2 of the boom **40** and the arm **50** are obtained by the above-described equations (1) and (2), using the position of the pivot point **63** of the bucket **60**. And, the relative bucket angle Θ_3 with respect to the arm **50** is as follows.

$$\Theta_3=\Theta_a-\Theta_1-\Theta_2$$

Further, an equation for uniformly maintaining the bucket angle while controlling the bucket **60** in accordance with the velocity of the bucket tip **64** is as follows. Firstly, the velocity V_2 of the pivot point **63** of the bucket **60** required is represented by the velocity V_3 of the bucket tip **64** in the following equation.

$$V_{2x}=V_{3x}+l_3\sin\Theta_a\Theta_a$$

Here

$$\Theta_a=(\Theta_1+\Theta-2+\Theta_3)$$

$$V_{2y}=V_{3y}-l_3\cos\Theta_a\Theta_a$$

The velocity V_2 of the bucket pivot point **63** obtained from the equation is converted to the angular velocities of the boom **40** and the arm **50**. Further, the following equation is used as a method for determining the position of the bucket tip **64** according to manipulating directions and directions so that the angle of the bucket **60** can not be limited to a certain angle and can be freely determined. Firstly, The equation of the relationship between the angular velocities of the links and the velocity of the bucket tip **64** is as follows.

$$\begin{bmatrix} V_{3x} \\ V_{3y} \end{bmatrix} = [J] \begin{bmatrix} \dot{\Theta}_1 \\ \dot{\Theta}_2 \\ \dot{\Theta}_3 \end{bmatrix}$$

where J is as follows.

$$[J] = \begin{bmatrix} -l_1 s1 - l_2 s12 - l_3 s123 & -l_2 s12 - l_3 s123 & -l_3 s123 \\ l_1 c1 + l_2 c12 + l_3 c123 & l_2 c12 + l_3 c123 & l_3 c123 \end{bmatrix}$$

Here

$$s1=\sin\Theta_1\ s2\sin\Theta_2\ s3=\sin\Theta_3$$

$$s12=\sin(\Theta_1+\Theta_2)\ s123=\sin(\Theta_1+\Theta_2+\Theta_3)$$

where the angular velocities $[\Theta]$ of the links are obtained in the following equation.

$$\begin{bmatrix} \dot{\Theta}_1 \\ \dot{\Theta}_2 \\ \dot{\Theta}_3 \end{bmatrix} = [J]^T \cdot [[J] \cdot [J]^T]^{-1} \cdot \begin{bmatrix} V_{3x} \\ V_{3y} \end{bmatrix}$$

Hereinafter, the above-mentioned manipulating modes for intuitional manipulation of the manipulating device will be explained.

In the first manipulating mode, the mode conversion switch **91** in the switch board **90** is converted to the

automatic mode, and then the pivot point **63** of the bucket **60** is determined in proportion to the first and second manipulating directions **21**, **22**, **23**, and **24** and their amounts, and the bucket **60** is manipulated by the bucket operational signals of the third manipulating direction **26** and **27**.

In the second manipulating mode, the automatic mode **92** and the bucket angle switch **94** is selected, and then the pivot point **63** of the bucket **60** is determined in proportion to the first and second manipulating directions **21**, **22**, **23**, and **24** and their amounts, and the bucket **60** is manipulated by the bucket operational signals of the third manipulating direction **26** and **27**, while the absolute angle of the bucket is maintained uniformly.

In the third manipulating mode, the levelling switch **92** is selected, and then the tip **64** of the bucket **60** is determined in proportion to the first and second manipulating directions **21**, **22**, **23**, and **24** and their amounts, and the bucket **60** is manipulated by the bucket operational signals of the third manipulating direction **26** and **27**.

In the fourth manipulating mode, both the levelling switch **92** and the bucket angle switch **94** are selected, and then the tip **64** of the bucket **60** is determined in proportion to the first and second manipulating directions **21**, **22**, **23**, and **24** and their amounts with the absolute angle of the bucket **60** maintained uniformly by a user, and the bucket **60** is manipulated by the bucket operational signals of the third manipulating direction **26** and **27**.

In the fifth manipulating mode, the levelling switch **92** and the switch **29** of the first manipulating device **20** are selected, and then the tip **64** of the bucket **60** is controlled so that its position is determined in a plane having a predetermined angle set by the ground angle switch **93** of the switch board **90**, in proportion to the first and second manipulating directions **21**, **22**, **23**, and **24** and their amounts.

The above-mentioned five modes are displayed on the display section **95** of the switch board **90**, so a user can easily recognize in which mode the excavator is operated.

The operation of the control system relevant to the pivoting body **70** and the running body **79** will be explained with reference to FIG. **1** hereinbelow.

The manipulation of the forward direction **31** of the first manipulating direction **31** and **32** of the second manipulating device **30** moves left and right chain belts **80** and **190** in the forward direction **31**, and the manipulation of the rearward direction **32** moves the belts **80** and **190** in the rearward direction **32**.

The manipulation of the right direction **33** of the second manipulating direction **33** and **34** of the second manipulating device **30** moves left and right chain belts **80** and **190** in the forward and rearward directions **81** and **192** respectively, thereby turning the excavator to the right, and the manipulation of the left direction **32** moves the belts **80** and **190** in the rearward and forward directions **82** and **191** respectively, thereby turning the excavator to the left.

The manipulation of the clockwise direction **36** about the X axis of the third manipulating direction **36** and **37** moves the upper pivoting body **70** in the clockwise direction **72**, and the manipulation of the counterclockwise direction **37** about the X moves the upper pivoting body **70** in the counterclockwise direction **72**, the velocities of the movements being in accordance with the amounts of the manipulations.

The pivot safety switch **38** prevent unintended pivoting operation during the manipulation in the first and second manipulating directions **31**, **32**, **33**, and **34**.

Preferably, if the second manipulating device is used for running operation, position detecting sensors **38** and **39** such as potentiometer, which are installed in the third manipulating direction, i.e., in the normal direction with respect to the forward and rearward direction, as shown in FIG. **4**, have structures which generate a same output during the forward and rearward directional manipulation.

By the electrical signals of the second manipulating device **30** which are in charge of the running of the excavator, the chain belts **80** and **190** are controlled so that the excavator moves forward during the manipulation in the forward direction **31** if the relative angle of the upper pivoting body **70** with respect to the lower running body **79**, which is detected and calculated by a pivot detecting sensor **75** and the control section **10**, is above 180 degree. The chain belts **80** and **190** are also controlled so that the excavator moves rearward during the manipulation in the forward direction **31** if the relative angle of the upper pivoting body **70** is not above 180 degree. Hence, the manipulating direction of a user coincides with the moving direction of the excavator.

As above-described, the control system of the excavator according to the present invention prevents fatigues and stresses of a user by providing a pair of manipulating devices each of which can be manipulated along three directions, thereby enabling easy manipulation of the excavator along directions with two hands, i.e., in three dimensional way, and hence increases efficiency of work. The control system of an excavator is easily manipulate a working device with multi-degree of freedom, by providing intuitional controlling relation between the manipulation of a user and the operation of the excavator and by providing various operational functions, so the work efficiency of the excavator is increased.

While the present invention has been particularly shown and described with reference to a particular embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be effected therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. An excavator which comprises:

a working device having a plurality of links comprising a boom attached to a tip of an upper pivoting body pivoting with respect to a lower running body, an arm attached to a tip of the boom, and a bucket attached to a tip of an arm;

a pivoting device for driving and pivoting the upper pivoting body with respect to the lower running body;

a running device for driving left and right chain belts of the lower running body;

hydraulic cylinders and hydraulic motors for actuating the working device, the pivoting device, and the running device;

hydraulic control valves for controlling quantities of hydraulic fluid supplied to the hydraulic cylinders and the hydraulic motors;

a boom angle detecting sensor installed between the upper pivoting body and the boom, for detecting a relative angular position of the boom with respect to the upper pivoting body;

an arm angle detecting sensor installed between the boom and the arm, for detecting the relative angular position with respect to the boom,

a bucket angle detecting sensor installed between the boom and the bucket, for detecting the relative angular position with respect to the arm;

a control system having a pair of manipulating devices each of which can be manipulated in at least three

directions so as to output electrical signals proportional to deviated amounts in selected directions among the directions from a neutral position thereof, a switch board on which a plurality of function switch are installed, for transferring a signal in accordance with a selected function and displaying the selected function, a control section for controlling quantities of hydraulic fluid supplied to the hydraulic cylinders and the hydraulic motors by receiving signals from the manipulating device, the switch board, and the angle detecting sensors and transferring the signals to the hydraulic control valves.

2. An excavator as claimed in claim **1**, wherein the pair of manipulating devices are a first manipulating device installed on a vertical manipulating plane, for driving the working device in accordance with a manipulating direction and an amount thereof and a second manipulating device installed on a horizontal manipulating plane, for driving the running device and the pivoting device in accordance with a manipulating direction and an amount thereof, the vertical manipulating plane having a same direction as a direction of a working plane of the working device.

3. An excavator as claimed in claim **2**, wherein the first manipulating device is manipulated in a first manipulating direction which is a first coordinate axis, in a second manipulating direction which is a second coordinate axis, and in a third manipulating direction which is a rotating direction about a third coordinate direction perpendicular to a plane formed by the first and second coordinate axes.

4. An excavator as claimed in claim **2**, wherein the second manipulating device is manipulated in a first manipulating direction which is a first coordinate axis, in a second manipulating direction which is a second coordinate axis, and in a third manipulating direction which is a rotating direction about a third coordinate direction perpendicular to a plane formed by the first and second coordinate axes, the manipulating directions being respectively corresponding to a forward or rearward running operation of the running device, a left or right turning operation of the running device, and a left or right pivoting operation of the pivoting device.

5. An excavator as claimed in claim **2**, wherein a pivot safety switch is installed on an outer surface of the second manipulating device so as to send a signal about the third manipulation direction of the second manipulating device when the switch is on.

6. An excavator as claimed in claim **1** further comprising:

a pivot detecting sensor installed between the upper pivoting body and the lower running body, for detecting the relative angle of the upper pivoting body with respect to the lower running body and transferring an angle signal to the control section.

7. An excavator as claimed in claim **1**, wherein forward and rear movement of the lower running body is controlled so as to coincide with the first manipulating direction of the second manipulating device in accordance with whether the relative angle of the upper pivoting body with respect to the lower running body detected by the pivot detecting sensor is above 180 degree or not.

8. An excavator as claimed in claim **1**, wherein a levelling switch for determining whether working ground surface should be levelled or not, a bucket angle switch for determining whether the absolute bucket angle should be maintained uniformly or not during the work, an ground angle switch for determining the inclined angle of the working surface during the levelling work, a mode conversion switch for converting the operational mode to a manual mode or an automatic mode are installed on the switch board, the switch board being provided with a display section for displaying information about operational states and modes of the excavator.

9. An excavator as claimed in claim **8**, wherein in case of the manual mode, operations of the boom, the arm, and the bucket are respectively controlled by the first, second, and third manipulating directions.

10. An excavator as claimed in claim **8**, wherein in case of the automatic mode, a pivot point of the bucket is determined by the first and second manipulating directions and manipulated amounts in the directions, and the bucket is manipulated by the third manipulating direction and manipulated amount.

11. An excavator as claimed in claim **9** or **10** further comprising:

a bucket selection switch installed on an outer surface of the first manipulating device, for transferring a signal to the control section about manipulated directions along the direction, and the manipulated amounts of the first manipulating device while the switch is on.

12. An excavator as claimed in claim **10**, wherein when the bucket angle switch is selected during the automatic mode operation, the absolute bucket angle is uniformly maintained by manipulating the relative bucket angle with respect to the arm, and during the operation of the bucket, the bucket is manipulated regardless of the other manipulations so that the absolute bucket angle is reset to a new value.

13. An excavator as claimed in claim **8**, wherein if the levelling switch is selected, the automatic mode is automatically selected, and a position of a bucket tip is determined by the first and second direction manipulation and manipulated amounts of the first manipulating device in the automatic mode, in accordance with the detected relative boom angle with respect to the upper pivoting body, the detected relative arm angle with respect to the arm, and the detected relative bucket angle with respect to the arm, the bucket being manipulated by the third manipulating direction and amount in the direction.

14. An excavator as claimed in claim **8**, wherein if both the levelling switch and the bucket angle switch are selected, the position of the bucket is determined and controlled by the manipulated direction and amount in the automatic mode of the first manipulating device, and then if a signal in accordance with the third manipulating direction is transferred to the manipulating device, the bucket is manipulated regardless of the other manipulations, and then if a bucket operational signal is not transferred to the manipulating device, the absolute bucket angle is maintained uniformly.

15. An excavator as claimed in claim **2**, further comprising:

a switch installed on a tip of the first manipulating device and connected to the control device, for controlling a point determined by the first manipulating direction and amount while the switch is on, so that the point is moved on a plane selected by the switch.

16. An excavator as claimed in claim **8**, wherein if the switch is on during the levelling work, the bucket tip determined by directions and amounts of the first and second manipulating direction is moved in a working plane having a certain angle selected by the ground angle switch.

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